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INSTRUCTION MANUAL

MODEL BA-5

ATTENUATION CALIBRATOR

Weinschel Engineering

KENSINGTON, MARYLAND

RETURN TO
AEROSPACE DIV.

INSTRUCTION MANUAL

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TABLE OF CONTENTS

Section		Page
I	GENERAL INTRODUCTION	1-4
	1.1 Scope of Manual	1
	1.2 Purpose of Equipment	1
	1.3 Specifications	1
	1.3.1 Attenuation Range	1
	1.3.2 Attenuator Accuracy	1
	1.3.3 Frequency	1
	1.3.4 Bandwidth	1
	1.3.5 Input Impedance	1
	1.3.6 Voltage Gain	1
	1.3.7 Maximum Output Voltage	1
	1.3.8 Equivalent Noise	1
	1.3.9 Bolometer Bias Current	1
	1.3.10 Output Impedance	2
	1.3.11 Controls	2
	1.3.12 Connectors	2
	1.3.13 Fuse	2
	1.3.14 Primary Power	2
	1.3.15 Ambient Temperature	3
	1.3.16 Dimensions	3
	1.3.17 Weight	3
	1.4 Description	3
	1.5 Unpacking and Preparation for Use	4
	1.6 Preliminary Precautions	4
II	THEORY OF OPERATION	5-8
	2.1 General	5
	2.2 Barretter	5
	2.3 The BA-5 Attenuation Calibrator	6
	2.3.1 The Barretter Biasing Circuit	6
	2.3.2 The Audio Substitution Attenuator	6
	2.3.3 The 1000 cps Amplifier	6
	2.3.4 The Indicator	7
III	OPERATING PROCEDURE	9-15
	3.1 A Single Channel Set Up	9
	3.1.1 The RF Source	11
	3.1.2 Bolometer and Bolometer Mount	11
	3.2 A Dual Channel Set Up	11
	3.3 Extension of the Range of Measurement	12
	3.3.1 Partial RF Substitution	12
	3.3.2 Use of a Barretter in Its Non-Linear Range	13

TABLE OF CONTENTS (Cont.)

Section		Page
IV	MAINTENANCE	16-31
	4.1 Introduction	16
	4.2 Scope of Procedure	16
	4.3 Operation and Use	16
	4.4 Specifications	16
	4.5 Procedures	17
	4.5.1 Test Equipment Required	17
	4.5.2 Tubes	17
	4.5.3 Components	17
	4.6 Performance Tests	18
	4.6.1 Power Supply Voltage Adjustment	19
	4.6.2 Center Frequency	19
	4.6.3 Bandwidth	19
	4.6.4 Voltage Gain	21
	4.6.5 Gain Control Range	21
	4.6.6 Attenuator Accuracy	21
	4.6.7 Meter Linearity	22
	4.6.8 Internal Noise	23
	4.6.9 Selective Feedback Networks	23

LIST OF ILLUSTRATIONS

Figure		Page
1	Block Diagram - BA-5	2
2	Front Panel View - BA-5	3A
3	Back Panel View - BA-5	8
4	Under Chassis View - BA-5	8A
5	Single Channel Block Diagram	10
6	Schematic	14
7	Correction Curve for Barretters	15
8	General Performance Test, Test Equipment Set Up.	20
9	Minimum Loss Pad	20
10	Noise, Test Equipment Set Up	24

LIST OF TABLES

Table		Page
I	Performance Specifications	16
II	Test Equipment Required	17
III	Cables Required	18
IV	Connectors Required	19
	PARTS LIST	25

SECTION I

GENERAL INTRODUCTION

1.1 SCOPE OF MANUAL

This manual covers the description, theory of operation, operating procedure, and maintenance instructions for the Model BA-5 Attenuation Calibrator.

1.2 PURPOSE OF EQUIPMENT

This equipment is intended to be used for the accurate measurement of rf power ratios when used with a square law detector and certain other equipment to be described later.

Power ratio measurements are required in many applications. Some typical examples are: determination of antenna patterns, insertion loss, amplifier gain and standing wave ratio. These applications will be treated in more detail in subsequent sections of this manual.

1.3 SPECIFICATIONS

1.3.1 Attenuation Range: Continuous over a range from 1 to 52 db at rf when using a square law detector; corresponds to a range from 2 to 104 db at the audio frequency used.

1.3.2 Attenuator Accuracy: Better than 0.02 db at rf for rf power ratios up to 30 db for any combination. Resolution capability is .002 db. Accuracy of a measurement is dependent on several other factors. See Sections 2 and 3.

1.3.3 Frequency: Audio - 1000 ± 3 cycles per second. RF - any for which bolometers, bolometer mounts and other required accessories are available. See Sections 2 and 3.

1.3.4 Bandwidth: Less than 35 cycles per second between 3 db points.

1.3.5 Input Impedance: Approximately 2000 ohms, Intended for use with bolometers, having a dc resistance between 50 and 200 ohms.

1.3.6 Voltage Gain: Between input and output connectors approximately 4×10^6 max. adjustable over a range of 80 db. At full gain and the attenuator at zero, approximately a 0.4 microvolt signal will produce full scale deflection on the output meter.

1.3.7 Maximum Output Voltage: 1.5 volts, rms to external indicator.

1.3.8 Equivalent Noise: Less than 30 millimicrovolts rms referred to the input when connected to a shielded 200 ohm wirewound resistor.

1.3.9 Bolometer Bias Current: Adjustable from 3-9 ma dc from a constant current supply. The bolometer can be connected or disconnected and the power switched on and off without damage to the bolometer.

1.3.10 Output Impedance: Approx. 250 ohms. Load impedance for minimum distortion should be greater than 10,000 ohms.

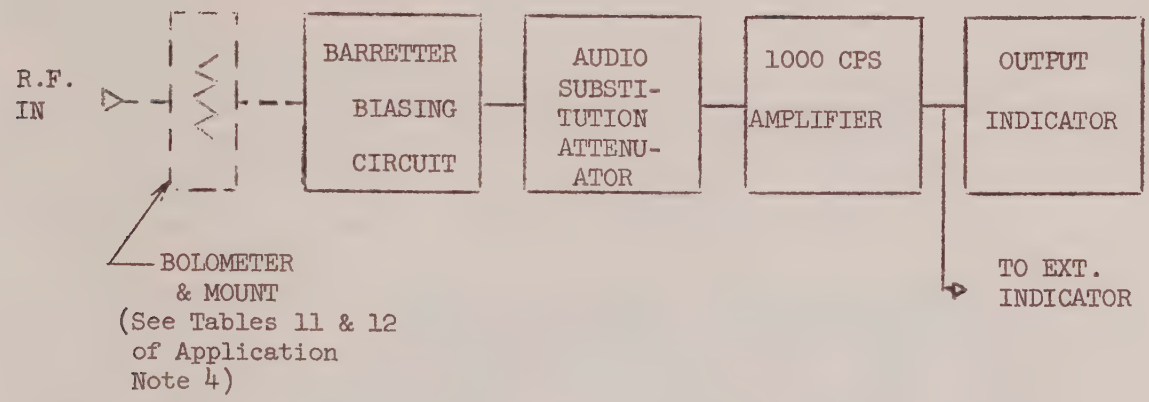


Figure 1 Block Diagram - BA-5

1.3.11 Controls: "Attenuation" - Four (4) lever switches - 10 db each; one eleven (11) position switch covering 0 to 10 db in 1 db steps; one twelve (12) position switch covering 0 to 1 db in one step and 1.0 to 2.0 db in 0.1 db steps; and a continuous control covering minus .01 to plus .11 db.

"Gain" - A coarse control with 7 steps of approximately 10 db (A.F.) each and a fine control with a continuous range of approximately 10 db (A.F.).

"Meter Time Constant" - A two position switch with "short" and "long" positions.

"Bolometer Current Adjust" - Screwdriver adjustment available from front panel.

"Power, On-Off" - Toggle switch with red pilot light indicator.

1.3.12 Connectors: "Bolometer" - BNC female, front panel mounted.
"Output" - BNC female, front panel mounted.
"Power" - Standard 115 volt, 3 contact recessed male cap on rear of chassis.

1.3.13 Fuse: 3 Amp. Bussman AGC, mounted on rear of chassis.

1.3.14 Primary Power: 105-125 volts, 60 cps, 190 va.

1.3.15 Ambient Temperature: 15°C to 35°C.

1.3.16 Dimensions: Standard relay rack mounting. Panel - 10-1/2 in. x 19 in. Maximum depth behind panel - 13-1/2 in.

1.3.17 Weight: 35 pounds.

1.4 DESCRIPTION

The Model BA-5 Attenuation Calibrator consists of a precision audio attenuator, a low noise amplifier selective to 1000 cps and an indicator provided with VSWR and db scales. A cathode follower output allows the use of an external meter or recorder. This output is also used when the instrument is used in the dual channel test set (see Section 3.2). A block diagram is shown in figure 1 and photographs of the equipment are shown in figures 2, 3 and 4.

In use, audio attenuation is substituted for rf attenuation to maintain the output constant. It is designed for use with a square law detector which means that the voltage input to the BA-5 is proportional to the power input to the bolometer. Therefore, a given change in rf level at the bolometer input (measured in decibels) results in twice this change (again measured in decibels) in the audio level. The substituted audio attenuation is, therefore, twice the rf attenuation. The audio attenuator on the BA-5 is calibrated in equivalent rf decibels when using a square law detector and this factor of two need not be considered unless the attenuator is used to measure attenuation at 1000 cps when the audio attenuation will be twice the indicated attenuation.

The audio attenuator impedance is 2000 ohms which produces negligible loading of the 200 ohm bolometer.

The BA-5 contains a constant current bolometer bias supply and is also provided with a meter indicating bolometer current. Bolometer current is continuously adjustable over a range of from 3 to 9 ma. It can also be turned off completely by rotating the control to its extreme CCW position. This is necessary if a crystal is used in place of a bolometer.

The audio attenuator is followed by a low noise, linear amplifier sharply selective to 1000 cps. By placing the amplifier after the attenuator, the amplifier operates at a constant level during any one measurement and small non-linearities in the amplifier response do not affect the accuracy of the measurement. The amplifier input circuit is carefully laid out and shielded to keep the noise pickup to a minimum. The amplifier may be operated within reasonable distance of ac power supplies and other 60 cycle equipment without excessive hum pickup.

The amplifier is followed by an indicator and cathode follower which provides an output for an external indicator or recorder.

The indicator is provided with a "short" and "long" time constant to allow accurate measurements to be made at levels such that the noise present would normally cause appreciable meter fluctuation. By using the "long" time constant under these conditions, the meter reading is averaged with very little resulting error.

P-150

Figure 2 Front Panel View - BA-5

The meter is provided with both VSWR and db scales so that the equipment can also be used for VSWR measurements in the usual manner.

1.5 UNPACKING AND PREPARATION FOR USE

The BA-5 is shipped in a double carton with three (3) inches of packing material between the ineer and outer cases. Normal care should be exercised in removing the instrument and packing material from the case. There should be no loose items with the exception of the line cord and the Instruction Manual. Tubes are shipped in place.

After unpacking the instrument, examine it for mechanical damage. If any damage is found, notify the shipping company immediately.

Remove the bottom cover of the chassis and examine the leads connecting the two floating chassis to insure that no lead has been broken in transit. Check ground connections. Erratic grounds can produce severe oscillation conditions which render the instrument useless. Remove the umper across the meter terminals and the blocks from the floating chassis.

Check the condition of the 3 amp Bussman AGC fuse. Be sure that all tubes are firmly seated.

Turn the bolometer bias control to its maximum counterclockwise position.

The other equipment required will depend on the purpose for which the instrument is to be used. (See Section 3). Although the instrument is thoroughly shielded, endeavor to keep it away from high intensity rf fields. Be sure that the line voltage is within the operating limits. If necessary, use an ac voltage regulator to provide the proper ac line voltage at all times or accuracy of instrument may be impaired.

1.6 PRELIMINARY PRECAUTIONS

Keep the coaxial input cable from the bolometer to the input of the BA-5 as short as conveniently possible. Under no circumstances, allow it to exceed three feet in length. Do not permit any coaxial cable to pass through a strong magnetic field at the modulating frequency since the cable shielding is ineffective against low frequency magnetic disturbances. Do not place the BA-5 too close to or in the same metal rack as the audio modulator for the rf source. Avoid ground loops when connecting shielded cable. If a stabilized voltage regulator is used, it is wise to keep it as far away as conveniently possible from the test set up.

After the above precautions have been observed, set the "coarse" and "fine" gain controls to their maximum counterclockwise position. Plug in the line cord and switch on the power. Allow the equipment to warm up for five minutes. Connect the bolometer cable to "Input" and set the bolometer current with a screwdriver through the hold in the front panel marked "Adjust" until the bolometer current meter indicates the correct operating current for the bolometer used.

The instrument is now ready for use.

SECTION II

THEORY OF OPERATION

2.1 GENERAL

The use of an audio substitution method of measurement of rf insertion loss is described in "Technique of Microwave Measurements" by C. G. Montgomery (Vol. 11 of the M.I.T. Rad. Lab. Series) pp. 806-808 and 838-841.

This method is based on the assumption that the application of a modulated rf signal to a biased bolometer results in a resistance variation in the bolometer that is proportional to the rf power applied. If this resistance variation is used to develop the input voltage to an amplifier or voltmeter, it is possible to measure power ratios at the bolometer input by measuring voltage ratios at the bolometer output. This measurement can be accomplished over a limited range by using a well-calibrated voltmeter and remembering that an N db change in audio level corresponds to an N/2 db change in the rf level.

A preferable method is to use an accurate audio attenuator in a substitution arrangement in which case the indicator is used only as an index to allow the operator to maintain the audio level constant as rf attenuation is inserted. The Model BA-5 has been designed to do this job with good accuracy and requires a minimum amount of operator skill. There are two recommended set ups in which it can be used. They are described in Section III, Operating Procedures.

2.2 BARRETTER

A barretter is used with this equipment since its thermal time constant is short enough so that the resistance variations follow the 1000 cycle modulation on the input rf signal and thereby produce a reasonable output voltage. The barretter also follows a square law quite closely over an appreciable power range. The departure from square law and means of correcting for it are discussed in paragraph 3.3.2.

In operation, the barretter is biased with a fixed current. When rf power is applied, the barretter resistance varies in accordance with this power. If a constant current bias supply is used, the voltage across the barretter varies according to the rf power dissipated in the barretter and if the rf input signal is square wave modulated at an audio rate, the audio voltage developed across the barretter is proportional to the rf power dissipated.

The BA-5 contains a well filtered, constant current barretter bias supply and a front panel meter so that the current can be continuously monitored. A screwdriver control, available from the front panel, allows adjustment of the bias current to the proper value for the barretter being used.

The barretter bias circuit used in the BA-5 has the added advantage that it allows the operator to connect and disconnect the barretter at will without danger of burning it out due to transient current surges.

2.3 THE BA-5 ATTENUATION CALIBRATOR

A block diagram of the BA-5 is shown in figure 1 and photographs in figures 2, 3 and 4. Figure 6 shows a schematic circuit diagram.

From figure 1, it can be seen that the BA-5 consists of four principal parts: the barretter biasing circuit, the audio substitution attenuator, the 1000 cps amplifier and the output indicator. The operation of each part is discussed below.

2.3.1 The Barretter Biasing Circuit: The importance of this circuit can be appreciated from paragraph 2.2 above. Any noise on the barretter bias current appears at the amplifier and limits the smallest signal that can be detected. Reference to the schematic, figure 5, will show the care that has been taken to filter the biasing current and to prevent damage to the barretter due to current surges that might otherwise occur during connection and disconnection of the barretter.

2.3.2 The Audio Substitution Attenuator: This consists of a series of switch selected, resistive "T" pads with a characteristic impedance of 2000 ohms. The attenuation can be varied in steps of 10 db, 1.0 db and 0.1 db. In addition, there is a continuous vernier that covers a range of slightly over 0.1 db for fine adjustments.

The relatively high attenuator impedance (2000 ohms) loads the barretter by a negligible amount since it is biased to approximately 200 ohms.

As explained in paragraph 2.1, the substituted audio attenuation in decibels is twice the rf attenuation being measured. To allow the measurements to be made with a minimum of computation, the audio substitution attenuator is calibrated directly in rf db.

2.3.3 The 1000 cps Amplifier: The amplifier consists of vacuum tubes V-5 through V-10 as shown in figure 6. The audio attenuator is terminated by resistor R-13 and potentiometer P-5 in parallel with the step-up transformer T-4 whose secondary drives the grid of V-5. Accuracy of the instrument is affected by the amplifier input impedance which will change if:

1. the inductance of the primary transformer changes,
2. the grid of V-5 draws current, or
3. the feedback gain of the input section consisting of V-5 and V-6 changes.

The amplifier input impedance is influenced by the input impedance of T-4 which is a parallel tuned "LCR" circuit where "L" is the primary inductance of the transformer, "C" is the transformed capacitance of the secondary winding plus the capacitor C-35 connected across the secondary, and "R" is the magnetic, eddy current and copper losses of the transformer. In parallel with this "R" is the input (grid-to-cathode) impedance of V-5 which is also transformed to the primary side. Amplifier tube V-5 will have a high grid-to-cathode impedance since the grid is connected to ground through T-4 and R-55, and the cathode is biased to approximately one volt. The feedback through the twin-T to the secondary of T-4 also influences the amplifier input impedance by tending to increase the load impedance of the secondary winding. This entire "LCR" arrangement is shunted by P-5 in series with R-13, a 2000 ohm wirewound resistor.

Since a substantial change in the primary inductance of T-4 seldom occurs, changes in the amplifier input impedance are mainly brought about when the grid of V-5 draws current or when the gain of the amplifier section consisting of V-5 and V-6 changes. The procedure described in paragraph 4.6.6 will correct for any change in the amplifier input impedance and should be performed every six months or whenever the BA-5 is suspected of inaccurate measurements.

The amplifier proper consists of two feedback amplifiers in cascade. The first employs a twin "T" feedback circuit tuned to 1000 cycles. At frequencies far from 1000 cycles, a large amount of negative feedback is applied to the grid of V-5, while at 1000 cycles, the feedback voltage is greatly reduced. The gain therefore at 1000 cycles is high and a resonant effect is noted. Medium and fine gain controls are located between the two halves of V-6. A coarse gain control is located between V-6 and V-7 and consists of a tapped voltage divider. Each step on the switch corresponds to a gain change of approximately 10 db. A feedback circuit similar to the one previously described is placed around V-9 and V-8. As indicated in the specifications paragraph 1.3.4, the over-all bandwidth is less than 35 cycles.

The substitution attenuator control providing the .01 db resolution is actually a precision potentiometer used as a gain control and located between the two halves of V-9.

A dual triode V-10 serves the functions of driving the output indicator and providing an output to drive an external indicator.

2.3.4 The Indicator: The germanium diodes, CR-2 and CR-3, rectify the output of one-half of V-10 to provide drive for the output indicator. The output meter is provided with a mirror scale, to allow accurate resetting of the indicator, and with a decibel scale and VSWR scale. The decibel scale makes it convenient to estimate small changes in attenuation and it should be borne in mind that the attenuation is in terms of rf loss, not audio. See Sections 1.4 and 2.1. The VSWR scale is also calibrated for use with a square law detector.

C-27 and C-28 provide for long and short indicator time constants respectively. The short time constant should be used except where it is required to make measurements employing low levels, such that the circuit noise causes an excessive fluctuation on the output indicator. Under these circumstances, the long time constant can be used to allow accurate determination of the indicator reading.

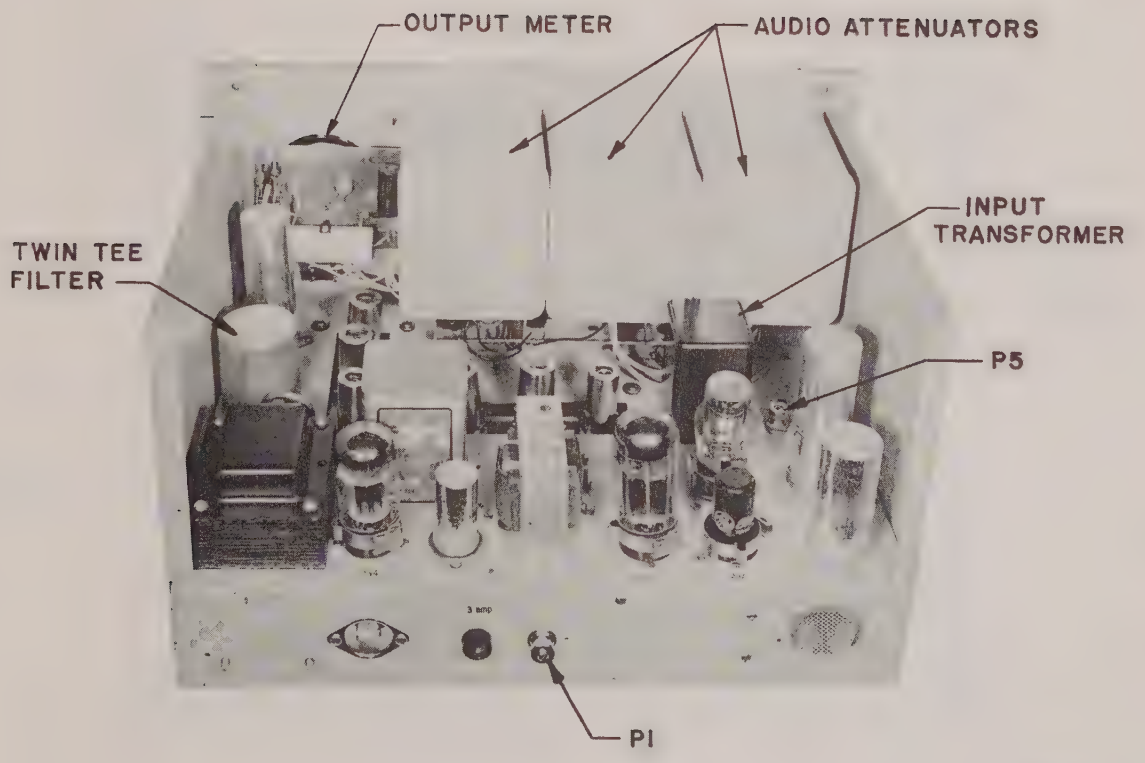


Figure 3. Back Panel View - BA-5

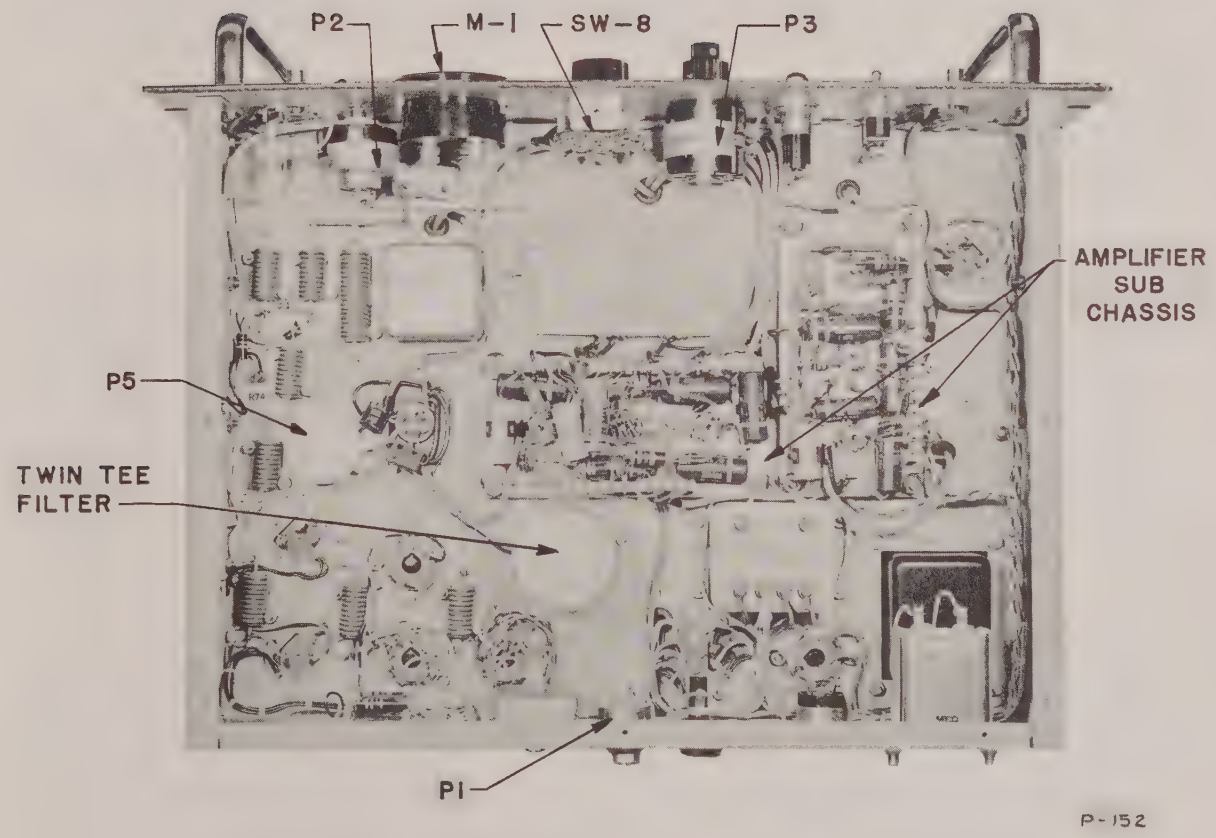


Figure 4. Under Chassis View - BA-5

SECTION III

OPERATING PROCEDURE

3.1 A SINGLE CHANNEL SET UP

The Model BA-5 can be used in the set up as shown in figure 5 to measure insertion loss up to 30 db at any frequency where the proper accessories are available. The range of 30 db is limited by the linear range of the barretters used and the internal noise of the BA-5. The accuracy with which measurements can be made using this set up is limited by the amplitude stability of the rf source and the resolution with which the output indicator can be returned to a given reading.

A 100% square wave modulated rf source with a power output of at least 20 milliwatts is employed as a power source. At least a 20 db, and preferably a 30 db, pad is used following the source to prevent any reaction on the source by insertion of the unit under test.

It is usually required that the insertion loss of a unit be measured between points having impedances equal to the characteristic impedance of the unit under test. If, therefore, the pad following the rf source does not have a low VSWR looking back toward the generator, a matching device, such as a double stub tuner, should be used following it. A slotted line and VSWR indicator is shown ahead of the unit under test, since it is usually required that a VSWR measurement be made at the same time as an insertion loss measurement. The rf signal is demodulated by means of a bolometer and the resulting 1000 cycle signal fed to the BA-5. The VSWR looking into the bolometer mount should be low if an accurate measurement is to be made. This can be done by use of a broad band bolometer mount or by use of a matching device such as a double stub tuner ahead of the mount.

In making this set up, and assuming the use of a Polytechnic Research and Development Model 610-A barretter, the maximum power applied to the barretter should not exceed 200 microwatts peak. This will provide an audio voltage of approximately 3 millivolts at the input to the BA-5. A convenient means of checking this is to set the gain controls on the BA-5 at their minimum (counterclockwise) position and all audio attenuators set to zero. The rf power is then adjusted to give a reading on the BA-5 output indicator of approximately full-scale. For this adjustment, the unit under test should, of course, be out of the set up.

To make a measurement, the audio substitution attenuator is set at a setting several db greater than the expected attenuation to be masured. The BA-5 gain is then adjusted to produce a convenient reading on the output indicator of approximately full scale. It is advisable to make this reading correspond to one of the fine divisions on the meter scale since it is easier to accurately reset the meter under these conditions. The unit under test is then inserted as shown in figure 5 and audio attenuation is removed until the original meter reading is obtained. The difference between the two settings of the audio attenuator is then equal to the attenuation of the unit under test.

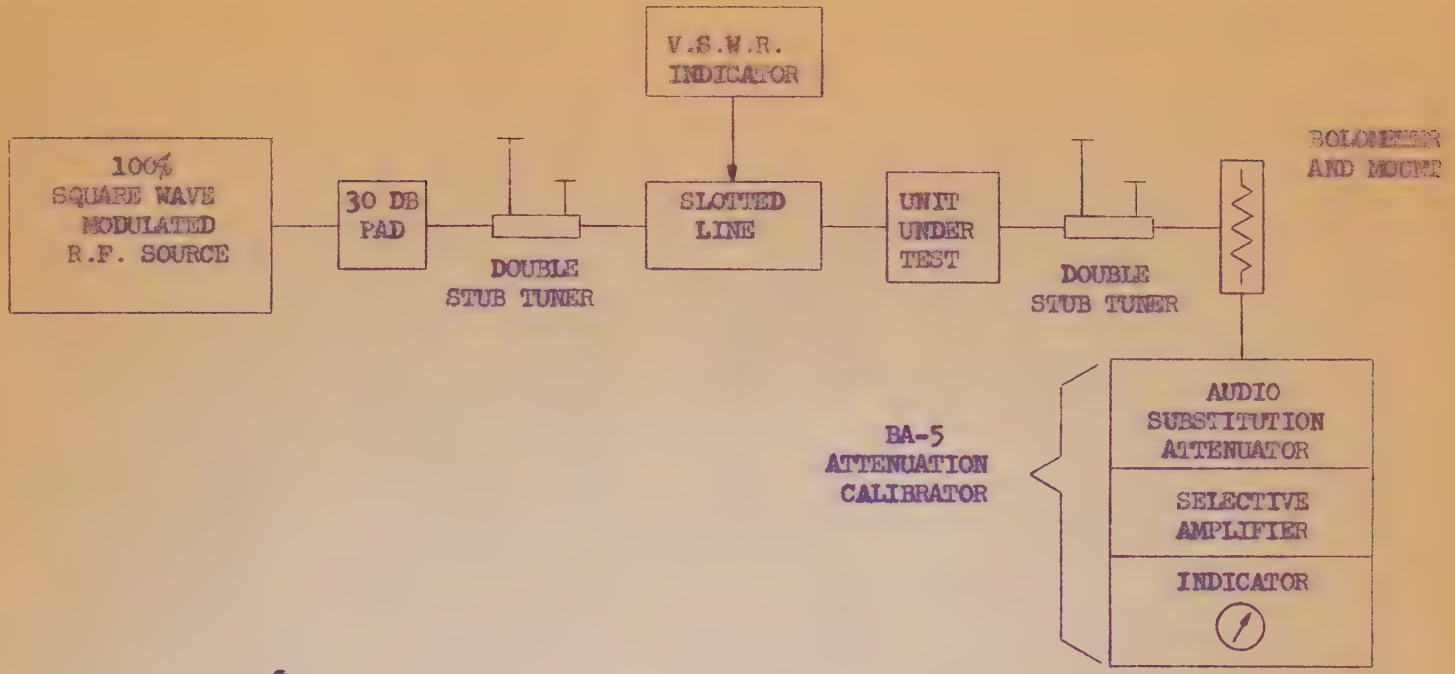


Figure 5. Single Channel Block Diagram

For the maximum accuracy to be obtained from the above procedure, it is necessary that the proper accessories be used. In the following paragraphs, some of the requirements of these accessories are set forth. There are several tables of recommended accessories shown in the Dual Channel Instruction Book, IM #41.

3.1.1 The RF Source: It is necessary that the rf source be 100% square wave modulated at 1000 cycles. The stability of the modulation frequency is important since a fairly narrow band amplifier is used in the BA-5. Weinschel Engineering makes sources covering the frequency range from 50 to 11,000 megacycles with built-in square wave modulators having the required stability. In addition, a Model MO-1A modulator is available for use with generators that do not have provision for internal square wave modulation at 1000 cycles. The rf source should be capable of delivering at least 20 milliwatts into a 50 ohm load. This allows 20 db of padding to be used following the generator. If additional power is available, additional padding can be used but, in no case, should less than 20 db be used. The generator should also possess a high degree of amplitude stability since any variation in the output during a measurement will result in an error. The generators manufactured by Weinschel Engineering are povided with a means of amplitude stabilization. A directional coupler is used to sample the incident power in the output line and this is fed back through the oscillator power supply to hold the output at a fixed level.*

The frequency stability of most sources is quite sufficient. However, a very great frequency shift cannot be tolerated if broad band components are not used in the set up. For instance, if a double stub tuner is used to provide the proper input impedance to a bolometer mount, this impedance can be very greatly dependent on frequency and a small frequency variation in the generator output can cause an appreciable error.

For a list of the recommended sources, see Dual Channel Instruction Manual, IM #41.

3.1.2 Bolometer and Bolometer Mount: As explained earlier, it is necessary that the bolometer used be provided with the proper biasing current. This biasing current should be determined for the particular bolometer being used and care should be taken to adjust it properly. A bolometer requiring a bias current of 4.5 milliamperes may burn out if as much as 4 milliwatts of rf power is added, while the ones employing a bias current of 8.75 milliamperes may burn out if 16 milliwatts of rf power is added. Dual Channel Instruction Manual, IM #41, list the recommended barretters and mounts for use with this set up.

3.2 A DUAL CHANNEL SET UP

In 3.1 above, a single channel set up employing the Model BA-5 is described. To increase the accuracy, particularly when measuring low insertion loss, a dual channel set up is advisable. Such a set up is described in Weinschel Engineering Dual Channel Instruction Manual. This set up permits measurements to 20 db which can be repeated with a precision of .01 db per 10 db. The sensitivity and short-time stability permits the operator to estimate variations of .001 db. The system has an absolute accuracy of .02 db per 10 db when used with the recommended accessories. For operation of Dual Channel, refer to the "Dual Channel Instruction Manual", IM #41.

* MS-1, 2, 3 only.

3.3 EXTENSION OF THE RANGE OF MEASUREMENT

The maximum insertion loss that can be measured using either a single channel or a dual channel set up is limited by noise at the low level and system non-linearity or available power at the high level. The system noise is an inherent characteristic of the system and is not under control of the operator, except insofar as careful set up and measurement techniques can reduce the hum pickup and other externally picked up noise to a minimum. However, certain of the non-linearities at the high level can be compensated for and, with certain precautions, an increased rf power level can be used.

3.3.1 Partial RF Substitution: As normally used in both the single and dual channel set ups, audio attenuation is substituted for rf attenuation in making a measurement. As explained above, due to the square law characteristic of the barretter, the substituted audio attenuation is twice the attenuation of the unit under test (all attenuation expressed in decibels). Therefore, to make a 20 db measurement, 40 db of substituted attenuation must be used. To reduce the amount of substituted audio attenuation for large attenuation measurements, it is possible to increase the rf power level used and, instead of substituting just audio attenuation, partial rf attenuation substitution can be used. For maximum accuracy, the attenuators used for rf substitution should be carefully calibrated on a dual channel set up.

The technique is essentially the same for both dual and single channel set ups but is more often used with a dual channel set up because of the lower attenuation range covered. The measurement of 40 db of attenuation with a dual channel set up will be used as an example. A 20 db attenuator is first calibrated using the dual channel set up in the normal manner as outlined in the Dual Channel Instruction Manual, IM #41.

The power input to the system is then increased by means which will be discussed later so that with the standard 20 db pad in place of the unit under test, the proper input is applied to the Model BA-5 calibrator. The 20 db pad is then removed and the 40 db unit to be calibrated is put in the set up. Audio attenuation is then removed to obtain a null on the Model ND-1 Differential Null Detector. The actual attenuation of the unit under test is then the difference in attenuation readings on the Model BA-5, plus the attenuation of the standard 20 db pad. Substantially the same procedure can be used with the single channel set up.

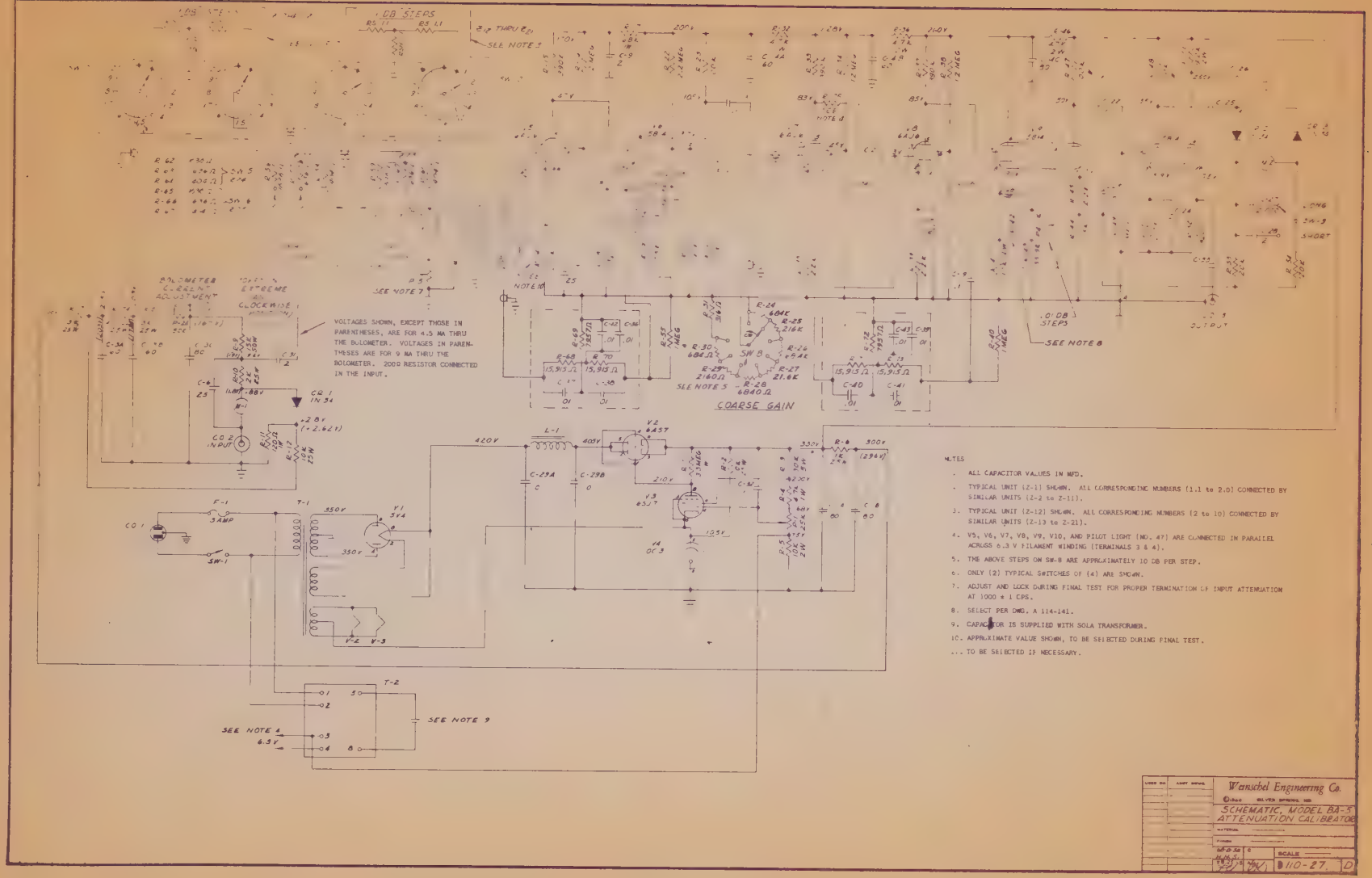
To increase the power available from the source, it is possible with proper precautions to decrease the amount of padding used following the rf source. These precautions are necessary to assure constant output from the generator with any variations in load that might occur during a test. One very satisfactory way of doing this consists of sampling the incident power in the line at the generator output and using this signal to regulate the source output so as to keep the incident power constant regardless of load. Weinschel Engineering's modulated sources MS-1, 2, and 3 are equipped for this type of operation. A regulator circuit is provided to accept a signal from a directional coupler and maintain the generator incident power output constant over a wide range of load conditions. A little reflection will show that the maintenance of a constant incident power corresponds to a condition wherein the generator is properly matched to the line since any power reflected from the load back to the generator has no effect on the generator incident power output.

3.3.2 Use of a Barretter in Its Non-Linear Range: Up until now, it has been assumed that the barretter is a true square law device, i.e., the voltage output is proportional to the power input. Any error arising from non-linearity of the barretter characteristic will be less than .01 db as long as the power input to the barretter is less than approximately 200 microwatts peak. The maximum power varies somewhat with barretter type, but the foregoing is a reasonably good average figure. It is possible, however, to extend the range of the barretter by approximately 10 db if proper account is taken of the error so introduced. Figure 7 shows a correction curve to be used when the barretters are operated at high power levels.

In practice, enough audio attenuation is always used with the BA-5 to insure that the BA-5 amplifier is never overloaded. Enough rf power is then used so that a reasonable indication can be obtained on the BA-5 when the required amount of attenuation for the measurement to be made is in the circuit. The unit under test is then inserted and audio attenuation removed for the usual indication.

The indicated or measured attenuation will now be less than the actual attenuation of the unit under test due to the non-linearity of the barretter characteristic. The required correction can be obtained from figure 7, which correction must then be added to the measured value.

The correction is plotted against the peak rf power level into the barretter. This power level is expressed in decibels relative to the power required to produce a 1000 cycle output voltage of 3.7 millivolts. This presentation is used because it has been found that the output voltage, not the input power, is the controlling parameter. The reference level of 3.7 millivolts is used because it is approximately this voltage that will produce full scale deflection of the BA-5 output meter with the gain controls set to minimum and all attenuators set to zero. The setting of the BA-5 attenuators to produce full scale deflection with gain set to minimum will give the value with which to enter figure 7. The voltage at the barretter output can be verified by a simple voltage measurement at the BA-5 input.

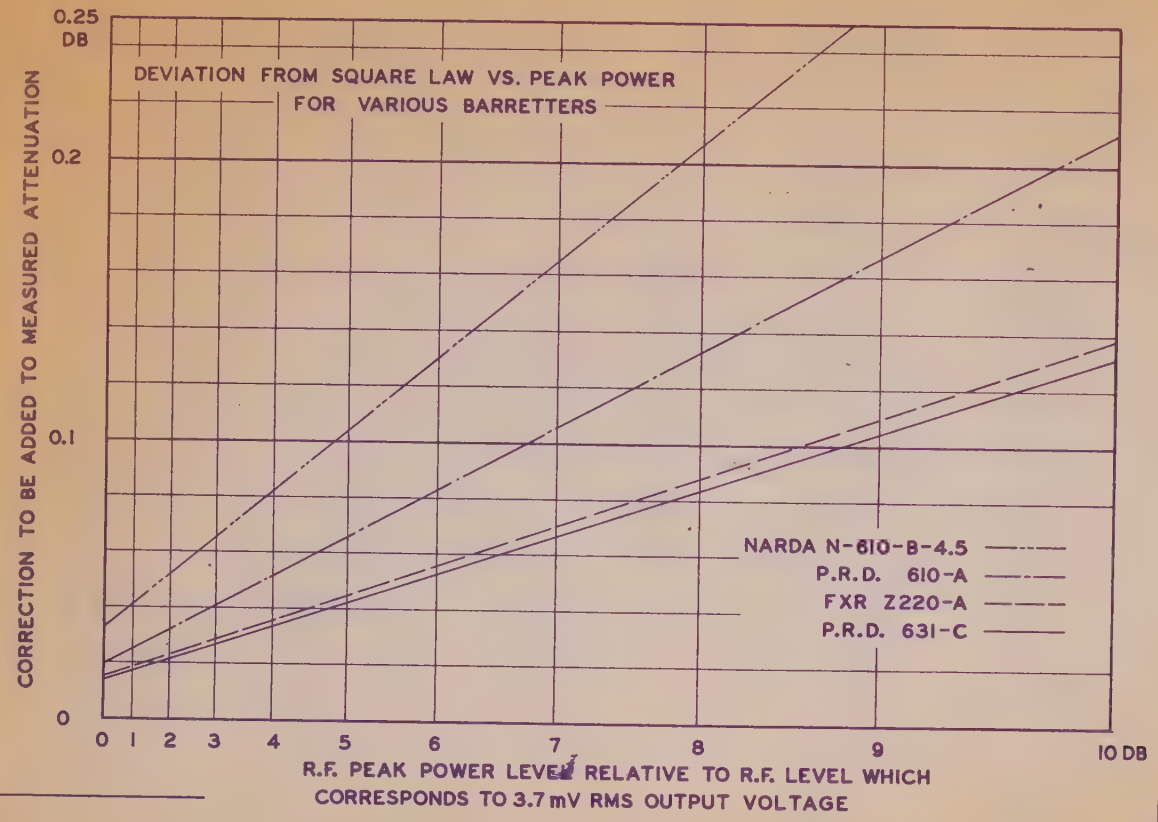


NOTES

1. ALL CAPACITOR VALUES IN MFD.
2. TYPICAL UNIT (Z-1) SHOWN. ALL CORRESPONDING NUMBERS (1.1 to 2.0) CONNECTED BY SIMILAR UNITS (Z-2 to Z-11).
3. TYPICAL UNIT (Z-12) SHOWN. ALL CORRESPONDING NUMBERS (2 to 10) CONNECTED BY SIMILAR UNITS (Z-13 to Z-21).
4. V5, V6, V7, V8, V9, V10, AND PILOT LIGHT (NO. 47) ARE CONNECTED IN PARALLEL ACROSS 6.3 V FILAMENT WINDING (TERMINALS 3 & 4).
5. THE ABOVE STEPS ON SW-B ARE APPROXIMATELY 10 DB PER STEP.
6. ONLY (2) TYPICAL SWITCHES OF (4) ARE SHOWN.
7. ADJUST AND LOCK DURING FINAL TEST FOR PROPER TERMINATION OF INPUT ATTENUATION AT 1000 ± 1 CPS.
8. SELECT PER DWG. A 114-141.
9. CAPACITOR IS SUPPLIED WITH SOLA TRANSFORMER.
10. APPROXIMATE VALUE SHOWN, TO BE SELECTED DURING FINAL TEST.
... TO BE SELECTED IF NECESSARY.

Wanschel Engineering Co.
SCHEMATIC, MODEL BA-5 ATTENUATION CALIBRATOR
SCALE
110-27
D

B80-77


DEVIATION FROM SQUARE LAW VS. PEAK POWER
FOR VARIOUS BARRETTERS
0.25 DB
0.2
0.1
0
CORRECTION TO BE ADDED TO MEASURED ATTENUATION
0 1 2 3 4 5 6 7 8 9 10 DB
R.F. PEAK POWER LEVEL RELATIVE TO R.F. LEVEL WHICH
CORRESPONDS TO 3.7 mV RMS OUTPUT VOLTAGE
NARDA N-610-B-4.5
P.R.D. 610-A
FXR Z220-A
P.R.D. 631-C

OCT 22 '62

REVISIONS

USED ON	ASSY. DRWG.
BA-5	

DIMENSIONS ARE IN INCHES
TOLERANCES

Weinschel Engineering
Kensington, Maryland

DEVIATION FROM SQUARE LAW
VS. PEAK POWER
FOR VARIOUS BARRETTERS

MATERIAL

FINISH

DKNOTT 3-18-58

SCALE

B80-77

SECTION IV

MAINTENANCE

4.1 INTRODUCTION

Maintenance requirements for this equipment are very simple.

4.2 SCOPE OF PROCEDURE

This document outlines the procedures to be followed in checking Attenuation Calibrator Model BA-5 for compliance with the original specifications (as guaranteed by the manufacturer at the time the equipment left the factory).

4.3 OPERATION AND USE

Operation and use of the equipment is covered in this instruction manual and the Dual Channel Instruction Manual, IM #41. Familiarity with the contents of these two documents is necessary before any servicing or recalibration is attempted.

4.4 SPECIFICATIONS

Performance specifications for Attenuation Calibrator Model BA-5 are given in Table I. In addition to checking for compliance with these specifications, several additional characteristics can be determined when performing the test procedures.

TABLE I

PERFORMANCE SPECIFICATIONS

Power requirement:	105 to 125 volts, 60 cps
Audio frequency:	1000 ± 3 cps
Audio frequency bandwidth:	Less than 35 cps between 3 db points
Voltage gain (approximate):	4×10^6 max. Approximately a 0.4 microvolt signal will produce full scale deflection on the output meter at full gain
Maximum output voltage	1.5 volts rms to external indicator
Gain control range:	80 db
Equivalent noise:	Less than 30 millimicrovolts rms referred to the input when connected to a shielded 200 ohm wirewound resistor
Attenuator accuracy:	Better than 0.02 db for rf power ratios up to 30 db

The Attenuation Calibrator has been designed to require a minimum of maintenance. However, should trouble develop and servicing become necessary, the usual procedures for maintenance of vacuum tube amplifiers applies. With extremely high gain amplifiers, conditions of oscillations are occasionally encountered. In the Attenuation Calibrator, oscillation is indicated by a steady reading on the output meter, with or without a connection being made to the input jack. This unstable condition is usually caused by a high resistance or broken ground connection.

4.5 PROCEDURES

Attenuation Calibrator Model BA-5 is a combination instrument consisting of a dc bolometer bias supply, a variable precision audio frequency attenuator, a high gain 1 kc amplifier, and an indicator with its associated circuitry. Because of the very high gain, special testing precautions are required and care must be taken in the interpretation of the results obtained from the tests. Since the Attenuation Calibrator is designed for use with square law detectors, all decibel scales are in terms of rf power level ratios at the detector input. To convert to af power level ratios, the readings must be doubled.

4.5.1 Test Equipment Required: The test equipment, cables and connectors required to perform the compliance test procedures are given in Tables II, III and IV.

4.5.2 Tubes: The checks usually made to determine the condition of vacuum tubes will normally suffice. The test described in 4.6.8 should be made if excessive noise originating from tube trouble is suspected.

4.5.3 Components: Resistance, capacitance and voltage values are shown in the schematic diagram, figure 6. Voltage measurements were made using a 20,000 ohms per volt meter.

TABLE II

TEST EQUIPMENT REQUIRED

Nomenclature	Model No.	Application	Range	Accuracy
Audio Oscillator (Hewlett-Packard Co.)	200CD	Variable oscillator	5 cps to 600 kc	
Universal Counter (Berkeley)	5510	Electronic counting	DC to 1,000,000 cps	± Crystal stability
Audio Attenuator (General Radio)	1450-TA	Variable attenuation	0 to 100 db in 10 db steps; 0 to 10 db in 1 db steps	± 0.005 db
Variac (General Radio)	W2	Line voltage control	0 to 130 volts at 2 amperes	± 3 percent

(Cont.)

TABLE II (Cont.)

Nomenclature	Model No.	Application	Range	Accuracy
Audio Vacuum Tube Voltmeter (Instrument Electronics Co.)	247	Measurement of ac voltages	0.5 mv to 500 volts rms	± 1 percent
Volt - Ohm Meter (Simpson) (2 required)	262	Measurement of ac and dc voltages	0 to 400 vdc; 0 to 160 vac	
Minimum Loss Pad*		Impedance Matching		
200 Ohm Shielded Wirewound Resistor (Weinschel Engineering Co.)	699	Termination		

* Necessary to manufacture locally. See Figure 9.

4.6 PERFORMANCE TESTS

The following tests are designed to indicate whether or not the equipment meets the specifications to which it has been guaranteed. Unless otherwise directed, set the following controls on the Attenuation Calibrator to the positions indicated prior to starting each test:

TABLE III

CABLES REQUIRED

Cable No.	Wire Type	Connectors	Length
1	RG-58A/U	UG88/U to UG88/U	3 feet
2	RG-58A/U	UG88/U to GR type 274NK	3 feet
3	RG-58A/U	UG88/U to GR Type 274NK	3 feet
4	RG-58A/U	UG88/U to GR Type 274NK	3 feet
5	RG-58A/U	GR Type 274NK to GR Type 274NK	1 foot

TABLE IV

CONNECTORS REQUIRED

Quantity	Type
2	UG-274A/U

Control	Position
METER TIME CONSTANT switch	SHORT
BOLOMETER CURRENT ADJUST	OFF (extreme counterclockwise)
ON - OFF toggle switch	ON

Also prior to starting each test, set the line input voltage to the Attenuation Calibrator to 117 vac by adjusting the Variac.

NOTE

For purposes of impedance matching, audio attenuator No. 2 should have a minimum of 20 db of attenuation inserted at all times. (See Figure 8).

4.6.1 Power Supply Voltage Adjustment: Apply primary power to the Attenuation Calibrator. Connect one volt-ohm meter, set on the 0-160 vac scale, across the line input terminals of the Attenuation Calibrator to monitor the ac line voltage. Connect the second volt-ohm meter, set on the 0-400 vdc scale, across capacitor C-1A to monitor the B plus voltage. Adjust potentiometer P-1 until the voltage across C-1A is 330 vdc when the line voltage is set to 117 vac.

Vary the line voltage by means of the Variac over the range of 105 to 130 vac. The change in voltage across C-1A should be less than one percent. Reset the Variac to 117 vac.

4.6.2 Center Frequency: Connect the equipment as shown on Figure 8. Set the COARSE and FINE GAIN controls on the Attenuation Calibrator to zero, and the audio oscillator frequency to approximately 1000 cps. Adjust the audio oscillator and audio attenuators to obtain a convenient output meter reading on the Attenuation Calibrator. Adjust the audio oscillator frequency for maximum output meter deflection. If necessary, readjust the audio oscillator output level to prevent driving the Attenuation Calibrator output meter off scale. The audio oscillator frequency should be 1000 ± 3 cps as measured with the Universal Counter.

4.6.3 Bandwidth: Connect the equipment as shown on Figure 8. On the Attenuation Calibrator, leave the COARSE and FINE GAIN controls maximum counterclockwise and the attenuator controls at zero. Adjust the audio oscillator frequency for maximum output meter deflection on the Attenuation Calibrator; then adjust the audio level until the output meter reads full scale or 0 db. Increase the audio

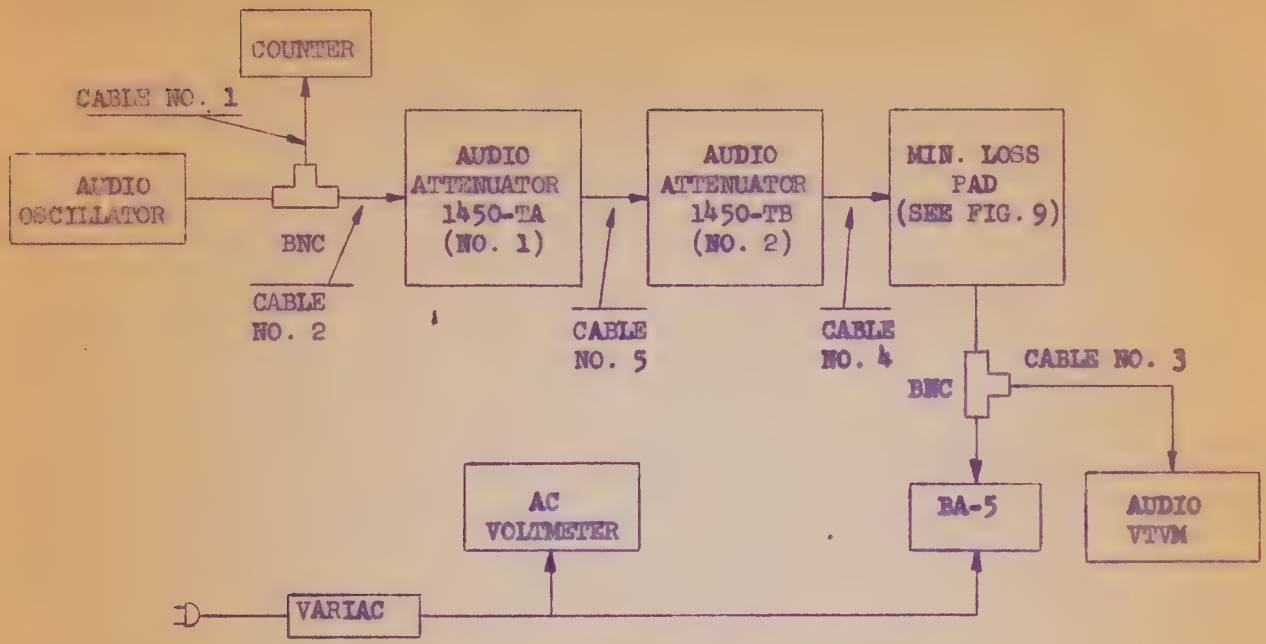


Figure 8. General Performance Test, Test Equipment Set-Up

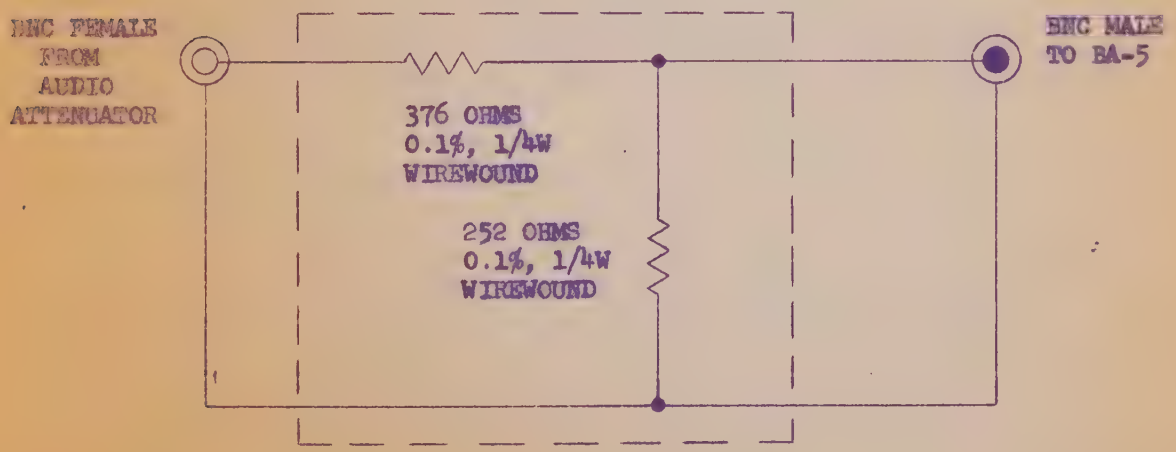


Figure 9. Minimum Loss Pad

frequency until the output meter reads 1.5 db. Measure and record this frequency. Decrease the audio frequency until the Attenuation Calibrator output meter passes through a maximum and again decreases to a reading of 1.5 db. Measure and record this frequency. The difference between the two recorded frequencies should be less than 35 cps. Note that 1.5 db as indicated on the meter corresponds to 3 db at the audio frequency.

Vary the audio frequency from 900 to 1100 cps. The output meter indication should go through a single maximum deflection.

4.6.4 Voltage Gain: Connect the equipment as shown on Figure 8. Set audio attenuator No. 1 to 20 db and audio attenuator No. 2 to 40 db. With the audio oscillator frequency adjusted to produce maximum output meter deflection on the Attenuation Calibrator, adjust the output level of the audio oscillator to produce an input voltage level of 1 millivolt to the Attenuation Calibrator. Set audio attenuator No. 1 to 90 db. On the Attenuation Calibrator, leave all attenuators set at zero and set the COARSE and FINE GAIN controls maximum clockwise. Adjust audio attenuator No. 1 to produce full scale deflection on the Attenuation Calibrator output meter. This should occur at a setting between 88 and 94 db. Then decrease the gain of the Attenuation Calibrator to minimum (COARSE and FINE GAIN controls maximum counterclockwise) and again decrease the attenuation of audio attenuator No. 1 to 20 db. Move the vacuum tube voltmeter from the input to the OUTPUT connector of the Attenuation Calibrator. With the signal adjusted for full scale output meter deflection, the voltage at the OUTPUT connector should be 1.5 ± 0.3 volts.

4.6.5 Gain Control Range: With the equipment connected as shown on Figure 8, set the GAIN controls on the Attenuation Calibrator maximum clockwise, the attenuators on the Attenuation Calibrator to zero, audio attenuator No. 1 to 90 db, audio attenuator No. 2 to 40 db, and the audio oscillator output to produce full scale deflection on the Attenuation Calibrator output meter. Reduce the gain of the Attenuation Calibrator to minimum and then remove attenuation from audio attenuator No. 1 until the output meter again reads full scale deflection. Audio attenuator No. 1 should have no more than 10 db of attenuation remaining.

4.6.6 Attenuator Accuracy:

NOTE

It is necessary to use an af signal generator with a very stable output for the following test procedure since any change in signal generator output level will show up as an error in the attenuator accuracy.

With the equipment connected as shown on Figure 8, insert 40 db of attenuation into audio attenuator No. 1 and 44 db of attenuation into audio attenuator No. 2. On the Attenuation Calibrator, rotate the COARSE GAIN control clockwise to its second position and set the FINE GAIN control to mid-range. At the audio oscillator, adjust the frequency to 1000.0 cps and the output level to provide a 0.3 mv input to the Attenuation Calibrator. On the Attenuation Calibrator, set all attenuators to zero and adjust the FINE GAIN control

for an output meter reference reading of 1.3 db. Now set one 0-10 db rf toggle switch to its 10 db rf position and remove 20 db from attenuator No. 1 The output meter on the Attenuation Calibrator should return to its original reading. Should the meter reading be off, adjust potentiometer P-5 to correct the meter reading. (Refer to Paragraph 2.3.3.) Insert 20 db of attenuation in audio attenuator No. 1 and remove the 10 db of attenuation inserted in the Attenuation Calibrator. Adjust the FINE GAIN control for a 1.3 db output meter reading. This procedure should be repeated several times until a meter reference reading of exactly 1.3 db is obtained for this 10 db rf insertion loss measurement. Then proceed by inserting 20 db of attenuation in the Attenuation Calibrator, using two 0-10 db rf toggle switches set to their 10 db rf positions, and removing 40 db of attenuation from audio attenuator No. 1. Now switch the 0 to 10 db rf selector switch to the 10 db rf position and remove 20 db of attenuation from audio attenuator No. 2. The total deviation for this 30 db rf insertion loss measurement should not exceed ± 0.02 db.

NOTE

Make sure that all cables are well shielded and all equipment is well grounded since any ground circuits or circuit loops will cause an error.

Repeat this procedure for checking the 0 to 2 and -.01 to .11 db rf vernier selector switches on the Attenuation Calibrator keeping in mind that the audio attenuation removed from the audio attenuators must be equal to twice the rf attenuation inserted in the Attenuation Calibrator to return the output meter reading to the reference value. The remaining 0 - 10 db rf toggle switches may be checked by inserting them one at a time into the line and switching the one that is already in the line to its 0 position.

4.6.7 Meter Linearity:

NOTE

1. The mechanical zero adjustment on the output meter of the Attenuation Calibrator has been preset at the factory and should never require readjustment. The following procedure should be used only if the adjustment has been disturbed.

2. Perform previous tests (4.6.1 through 4.6.6) prior to making this adjustment.

Connect the equipment as shown in Figure 8. Set all attenuators on the Attenuation Calibrator to zero and rotate the COARSE GAIN control fully counterclockwise. Rotate the FINE GAIN control to its mid position. Insert 40 db of attenuation into audio attenuator No. 1 and 20 db of attenuation into audio attenuator No. 2. Adjust the frequency and amplitude of the audio oscillator until the output meter of the Attenuation Calibrator indicates 0.5 db.

Remove 1 db of attenuation from audio attenuator No. 1. The output meter should indicate full scale (0 db). Insert 1 db of attenuation back into audio attenuator No. 1 to bring the meter indication back to 0.5 db. Insert attenuation into audio attenuator No. 1 in 1-db steps and observe the output meter of the Attenuation Calibrator change in 0.5-db steps until it indicates 10 db.

The permissible deviation is as follows:

Up to 3 db:	Less than ± 0.02 db
Between 3 db and 5 db:	Less than ± 0.1 db
Between 5 db and 10 db:	Less than ± 0.2 db

If the deviation exceeds these limits, an adjustment of the mechanical zero of the Attenuator Calibrator output meter (meter panel screwdriver adjustment) should be made and the procedure repeated. This adjustment is made between 0.5 and 3.0 db. Remove attenuation from audio attenuator No. 1 and adjust the FINE GAIN control of the BA-5 until the BA-5 output meter indicates 0.5 db. Next, insert 5.0 db attenuation at audio attenuator No. 1. The meter is now mechanically adjusted to read 3.0 db. Repeat this procedure until the meter is within the specifications between 0.5 and 3.0 db. Repeat the test described in the previous paragraph to be sure the output meter is within specifications from 0 to 10.0 db.

After this adjustment has been made, the procedure should be repeated using the 1-db steps of the Attenuation Calibrator instead of the audio attenuator. Now the meter indication will change in 1-db steps. The 0.1-db steps of the Attenuation Calibrator may be used to check between 0.5 db and 0 db, and between 0.5 db and 1.0 db. The same permissible deviation applies.

4.6.8 Internal Noise: Connect the equipment as shown on Figure 10. On the Attenuation Calibrator, set all attenuators to zero and GAIN controls maximum clockwise. The output voltage as read on the audio vacuum tube voltmeter should be less than 150 millivolts. This output voltage should be independent of the setting of the BOLOMETER CURRENT ADJUST. Care should be exercised in making this measurement to be certain that the 200 ohm resistor connected to the Attenuation Calibrator input is well shielded. The resistor must be wirewound since a composition resistor can introduce an appreciable amount of noise. The audio VTVM must be connected to the OUTPUT connector of the Attenuation Calibrator by means of a shielded cable to prevent pickup of undesired signals in the leads. Also make sure that no strong magnetic fields (such as those originating from heavy motors, etc.) are present since they might contribute excessive hum signals which would show up as noise.

4.6.9 Selective Feedback Networks: Two twin-tee networks are used in feedback circuits to determine the amplifier bandwidth. The bandwidth between 3 db points should be approximately 35 cps centered at 1000 cps. If either the bandwidth or center frequency is found to be outside of the specifications and the trouble is isolated to one of the twin-tee networks, the equipment should be returned to the factory for repair.

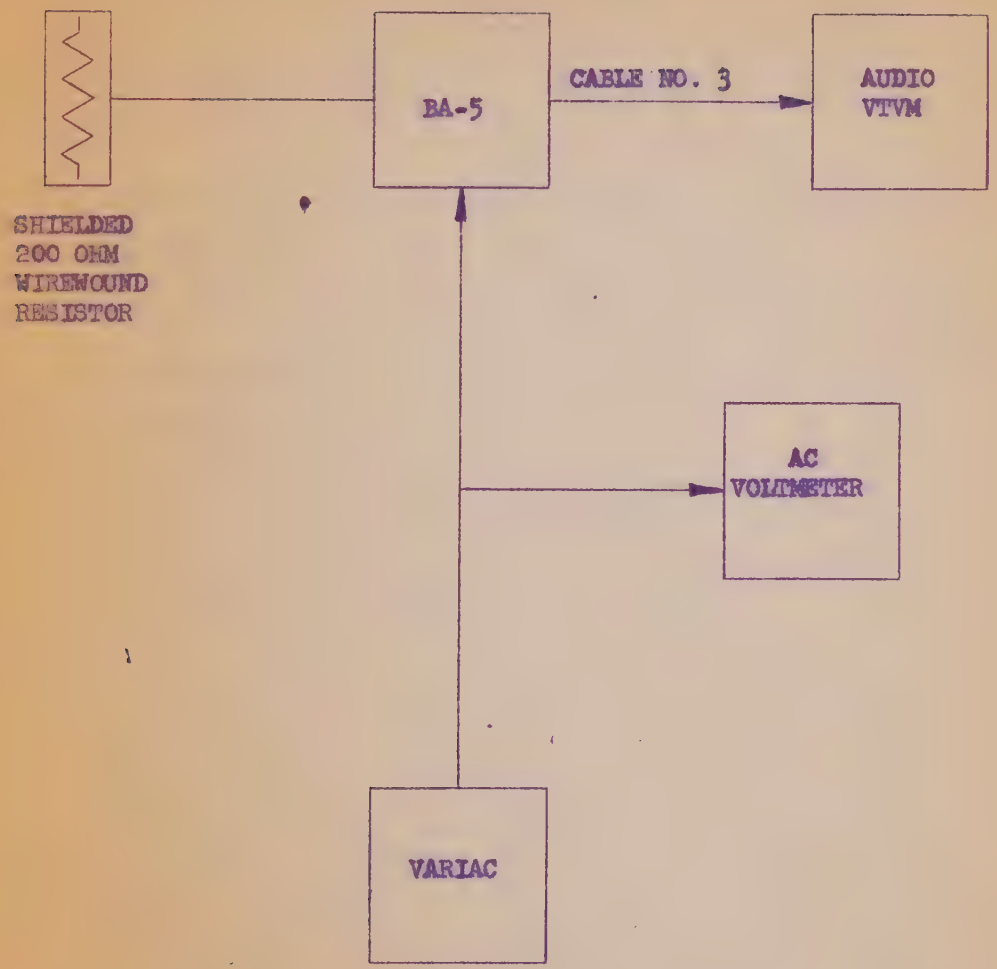


Figure 10. Noise, Test Equipment Set-Up

PARTS LIST

Schematic Symbol	Description	Weinschel Part No.
C1A, B	Capacitor, Elect, 2 Section, 80/80 mfd, 350V	32-9
C2	Not Used	
C3, A, B, C	Capacitor, Elect, 3 Section 60/60/80 mfd, 350V	32-10
C4	Not Used	
C5	Not Used	
C6	Capacitor, Elect, 25 mfd, 50V	31-4
C7	Same as C6	31-4
C8	Capacitor, Molded paper, .1 mfd, 400V	33-2-R1
C9	Capacitor, Elect, 2 mfd, 450V	31-12
C10	Same as C8	33-2-R1
C11	Capacitor, Molded paper, .05 mfd, 400V	33-2-R05
C12	Same as C11	33-2-R05
C13	Same as C8	33-2-R1
C14A, B, C	Same as C3	32-10
C15	Not Used	
C16	Not Used	
C17	Same as C6	31-4
C18	Same as C8	33-2-R1
C19	Same as C8	33-2-R1
C20	Same as C11	33-2-R05
C21	Same as C8	33-2-R1
C22	Capacitor, Molded paper, .01 mfd, 400V	33-2-R01
C23	Capacitor, Elect, 10 mfd, 50V	31-3

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
C24	Capacitor, Met. paper, 1 mfd, 200V	33-6-1
C25	Same as C8	33-2-R1
C26	Capacitor, Elect, 10 mfd, 450V	31-5
C27	Capacitor, Elect, 2000 mfd, 6V	31-1
C28	Capacitor, Met. paper, 2 mfd, 200V	33-6-2
C29	Capacitor, Elect, 10/10 mfd, 450V	32-11
C30	Not Used	
C31	Capacitor, Paper, bathtub type, 2 mfd, 600V	35-1
C32	Capacitor, Paper, bathtub type, 1 mfd, 400V	35-14
C33	Same as C8	33-2-R1
C34	Same as C8	33-2-R1
C35	Capacitor, Silver mica, To be selected: approx. value .0007 mfd	
C36	Capacitor, Silver mica, .01 mfd, 300V	34-2-R01
C37	Same as C36	34-2-R01
C38	Same as C36	34-2-R01
C39	Same as C36	34-2-R01
C40	Same as C36	34-2-R01
C41	Same as C36	34-2-R01
C42	Same as C36	34-2-R01
C43	Same as C36	34-2-R01
C01	Connector, male, AC line, 3-Pin Motor Base	62-38
C02	Connector, Coaxial, UG-928/U	63-14
C03	Same as C02	63-14
CR1	Diode, Crystal, 1N34	12-1

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
CR2	Same as CR1	12-1
CR3	Same as CR1	12-1
F1	Fuse, 3 amperes	52-1-3
L1	Choke, Filter	40-66
M1	Meter, 0-10 MADC	16-1
M2	Meter, 0-200 μADC, VSWR	A114-117
P1	Resistor, Variable, W/W 25K, 2W	20-9
P2	Resistor, Variable, W/W, 50K ohms, 4W	20-44
P3	Resistor, Variable, W/W, 15K/3K, 3W	20-10
P4	Resistor, Variable, W/W, 1K, 4W, includes R42	A114-141
P5	Resistor, Variable, W/W, 2K, 4W	20-43
R1	Resistor, Comp, 3.3 Megohms, 10%, 1W	25-2-3R3M
R2	Resistor, Wirewound, 10K ohms, 5%, 25W	26-8-10K
R3	Resistor, Wirewound, 28K ohms, 5%, 5W	26-6-28K
R4	Resistor, Comp, 4.7K ohms, 10%, 1W	25-2-4700
R5	Resistor, Comp, 10K ohms, 10%, 2W	25-3-10K
R6	Resistor, Wirewound, 1K ohms, 5%, 25W	26-8-1000
R7	Resistor, Wirewound, 3K ohms, 5%, 25W	26-8-3000
R8	Same as R7	26-8-3000
R9	Resistor, Wirewound, 15K ohms, 5%, 50W	26-9-15K
R10	Resistor, Wirewound, 2K ohms, 5%, 25W	26-8-2000
R11	Resistor, Comp, 120 ohms, 10%, 1W	25-2-120
R12	Same as R2	26-8-10K
R13	Resistor, Comp, 2K ohms, 1%, 1/2W	26-2-2000
R14	Resistor, Comp, 2.2K ohms 10%, 1/2W	25-1-2200

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
R15	Resistor, Comp, 390K ohms, 10%, 1/2W	25-1-390K
R16	Resistor, Comp, 1.2 Megohms, 10%, 1/2W	25-1-1R2M
R17	Resistor, Comp, 68K ohms, 10%, 1W	25-2-68K
R18	Resistor, Comp, 10K ohms, 10%, 1/2W	25-1-10K
R19	Resistor, Comp, 7.5K ohms, 5%, 1/2W	25-8-7500
R20	Resistor, Comp, 47K ohms, 10%, 1/2W	25-47K
R21	Same as R18	25-1-10K
R22	Resistor, Comp, 2.2 Megohms, 10%, 1/2W	25-1-2R2M
R23	Resistor, Comp, 100K ohms, 10%, 1/2W	25-1-100K
R24	Resistor, Film, 684K ohms, 1%, 1/3W	25-13-684K
R25	Resistor, Film, 216K ohms, 1%, 1/3W	25-13-216K
R26	Resistor, Film, 68.4K ohms, 1%, 1/3W	25-13-68440
R27	Resistor, Film, 21.6K ohms, 1%, 1/3W	25-13-21600
R28	Resistor, Film, 6840 ohms, 1%, 1/3W	25-13-6840
R29	Resistor, Film, 2160 ohms, 1%, 1/3W	25-13-2160
R30	Resistor, Film, 684 ohms, 1%, 1/3W	25-13-684
R31	Resistor, Film, 316 ohms, 1%, 1/3W	25-13-316
R32	Same as R4	25-2-4700
R33	Same as R15	25-1-390K
R34	Same as R16	25-1-1R2M
R35	Same as R14	25-1-2200
R36	Resistor, Comp, 4.7K ohms, 10%, 2W	25-3-4700
R37	Same as R15	25-1-390K
R38	Same as R16	25-1-1R2M
R39	Same as R14	25-1-2200

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
R40	Resistor, Comp, 1 Megohms, 10%, 1/2W	25-1-1M
R41	Same as R5	25-3-10K
R42	See P4	
R43	Resistor, Wirewound, 33.3K ohms, 1%, 1/2W	25-4-33300
R44	Resistor, Comp, 1.5K ohms, 10%, 1/2W	25-1-1500
R45	Same as R14	25-1-2200
R46	Same as R36	25-3-4700
R47	Resistor, Comp, 100K ohms, 10%, 1W	25-2-100K
R48	Same as R47	25-2-100K
R49	Same as R40	25-1-1M
R50	Resistor, Comp, 2.7K ohms, 10%, 1/2W	25-1-2700
R51	Resistor, Comp, 8.2K ohms, 10%, 2W	25-3-8200
R52	Resistor, Comp, 820 ohms, 10%, 1/2W	25-1-820
R53	Resistor, Comp, 120K ohms, 10%, 1/2W	25-1-120K
R54	Same as R53	25-1-120K
R55	Same as R40	25-1-1M
R56 through R67	Part of Z22, Z23, Z24, Z25	
R68	Resistor, Wirewound, 15,915 ohms, .1%, 1/2W	26-2-15915
R69	Resistor, Wirewound, 7957 ohms, .1%, 1/2W	26-2-7957
R70	Same as R68	26-2-15915
R71	Same as R68	26-2-15915
R72	Same as R69	26-2-7957
R73	Same as R68	26-2-15915
R74	Resistor, Wirewound, 400 ohms, 5%, 25W	26-8-400

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
SW1	Switch, Toggle, SPST	55-1
SW2	Switch, 2 Pole, 12 Position	56-3
SW3	Same as SW2	56-3
SW4	Switch, Lever, DPDT	57-4
SW5	Same as SW4	57-4
SW6	Same as SW4	57-4
SW7	Same as SW4	57-4
SW8	Switch, Rotary, 1 Pole, 11 Position	56-1
SW9	Switch, Toggle, 2 Circuit, 2 Position	55-2
T1	Transformer, Power, Plate & Fil.	40-57
T2	Transformer, with capacitor 1010-5, Fil., .5 mfd.	40-2
T3	Not Used	
T4	Transformer, Input	40-47
V1	Tube, Electron, 5V4	10-1
V2	Tube, Electron, 6AS7	10-3
V3	Tube, Electron, 6SJ7	10-4
V4	Tube, Electron, 0C3	10-5
V5	Tube, Electron, 6AU6	10-2
V6	Tube, Electron, 5814	10-7
V7	Same as V5	10-2
V8	Same as V5	10-2
V9	Same as V6	10-7
V10	Same as V6	10-7
Z1	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-1

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
Z2	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-2
Z3	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-3
Z4	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-4
Z5	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-5
Z6	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-6
Z7	Network, Attenuation,(Consists of 2 series and one shunt resistor)	26-24-7
Z8	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-8
Z9	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-9
Z10	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-10
Z11	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-11
Z12	Same as Z1	26-24-1
Z13	Same as Z11	26-24-11
Z14	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-12
Z15	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-13
Z16	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-14
Z17	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-15
Z18	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-16

(Cont.)

Schematic Symbol	Description	Weinschel Part No.
Z19	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-17
Z20	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-18
Z21	Network, Attenuation, (Consists of 2 series and one shunt resistor)	26-24-19
Z22 through Z25	Same as Z21	26-24-19

WARRANTY

Weinschel Engineering warrants each instrument of its manufacture to be free from defects in material and workmanship. Our obligation under this warrant is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to making good at our factory any part or parts thereof (except tubes, fuses, or batteries) which shall, within one year after making delivery to the original purchaser, be returned to us with transportation charges prepaid, and which on our examination shall disclose to our satisfaction to have been defective.

Weinschel Engineering reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or liabilities on the part of Weinschel Engineering.

Weinschel Engineering neither assumes nor authorizes any other person to assume for them any other liability in connection with the sale of their instruments and equipment.

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